# New metrics to measure snow-forest interactions in a maritime environment using ASO lidar

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## Introduction

Forest cover modifies snow accumulation and ablation rates via canopy interception and changes in sub-canopy energy balance processes. Lidar allows for a detailed characterization of forest structure elements both horizontally and vertically. New metrics to characterize the 2-dimensional structure of forests are needed to better capture canopy interception processes in hydrologic modelling. Canopy gap size is typically considered as a single spatial value that is uniform vertically. Here we present new methods for vertical characterization and the impacts of scale on new metrics for forest structure characterization.

**Study Objectives:**

1) How do forest metrics change when viewed vertically rather than horizontally?
2) How can we improve forest structure characterization?
3) How does scaling affect forest structure parameters?

**Study Site:** The Forest Elevation Snow Transect (ForEST) network is a five-year on-going study that spans the rain-snow transition zone to the upper seasonal snow zone In the Oregon Cascades, USA. The ForEST network is comprised of six snow-climate monitoring stations consisting of open and forested site pairs at three elevations Low (1150 m), Mid (1325 m) and High (1465 m) (Figures 1 &2).

Figure 1: Left column: Low-, Mid-, High-Open sites; Right column: Low-, Mid, High-Forest sites.

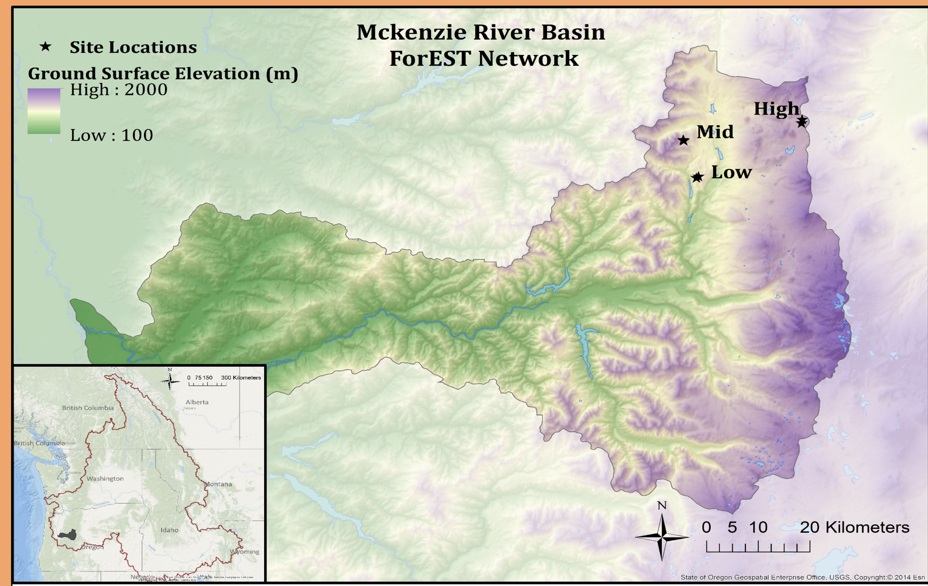


Figure 2: The ForEST network sites of the McKenzie River Basin with the greater Columbia River Basin (inset).

## Methods

**Lidar**:

A lidar 'Snow-On' flight overpass was performed by the NASA Airborne Snow Observatory (ASO) in March 2016. A Riegl Q1560 scanning lidar was used. Lidar outputs were tiled into 100x100m tiles and analyses performed at various scale within each tile. Relative height densities were calculated for each ForEST network site (Figure 6).

**Forest Structure Metrics**:

Gap size metrics are analyzed through discrete vertical 'slices' of the ASO lidar return data cube at 1-m vertical resolution over a 100×100-m pixel (Figure 3). At each height a horizontal two-dimensional (2D) slice of the lidar returns is analyzed to determine canopy presence (absence) relative to the ground surface. Each subsequent slice is then analyzed to determine the gap sizes and a distribution of gap sizes for each slice within the data cube is then found. Gap size change with height is then determined for each gap within the canopy across scales (Figures 7 & 9).

**Gap Size Stereology:**

Gap sizes are calculated using a stereological approach at each discrete vertical slice within the data cube. Stereology is a way of extracting 3-dimensional information from measurements made on 2-dimensional planar sections. Mean surface area per unit volume (SSV) is calculated anistropically from canopy presence/absence data. Methods follow those of Davis and Dozier (1989) and Lehto et al., (2014).

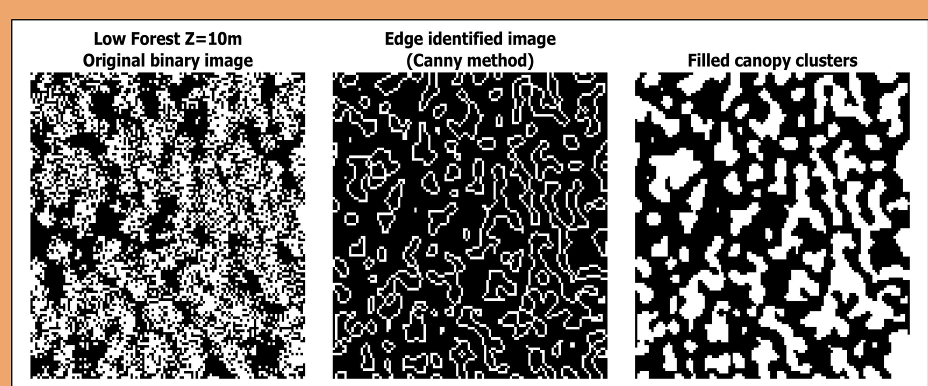


Figure 3: Forest canopy and gap identification steps performed for each vertical slice.

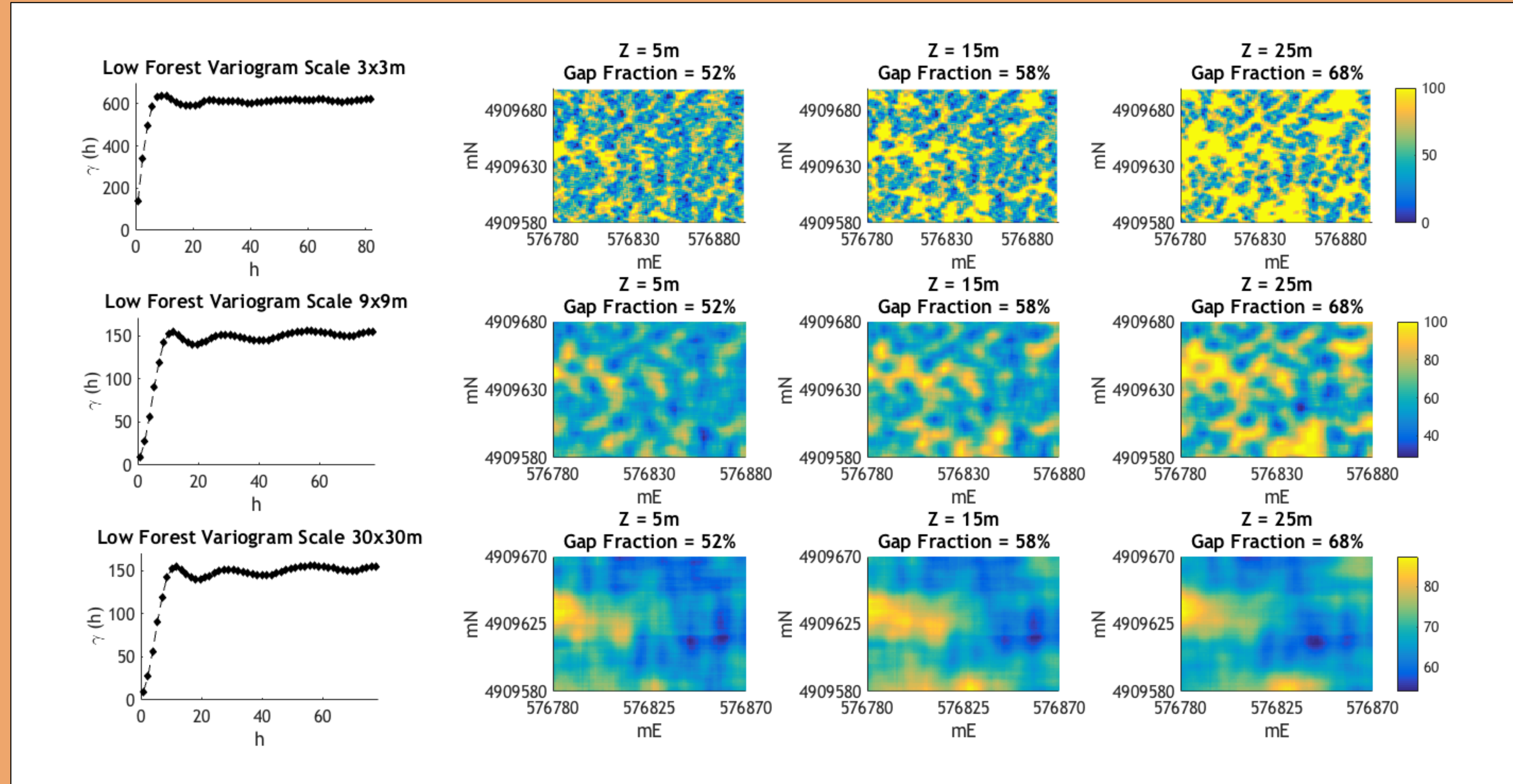


Figure 4: Calculated variogram analysis at three scales (column 1); Calculated gap fraction statistics for three z heights across three scales (columns 2 - 4) at the Low-Forest site.

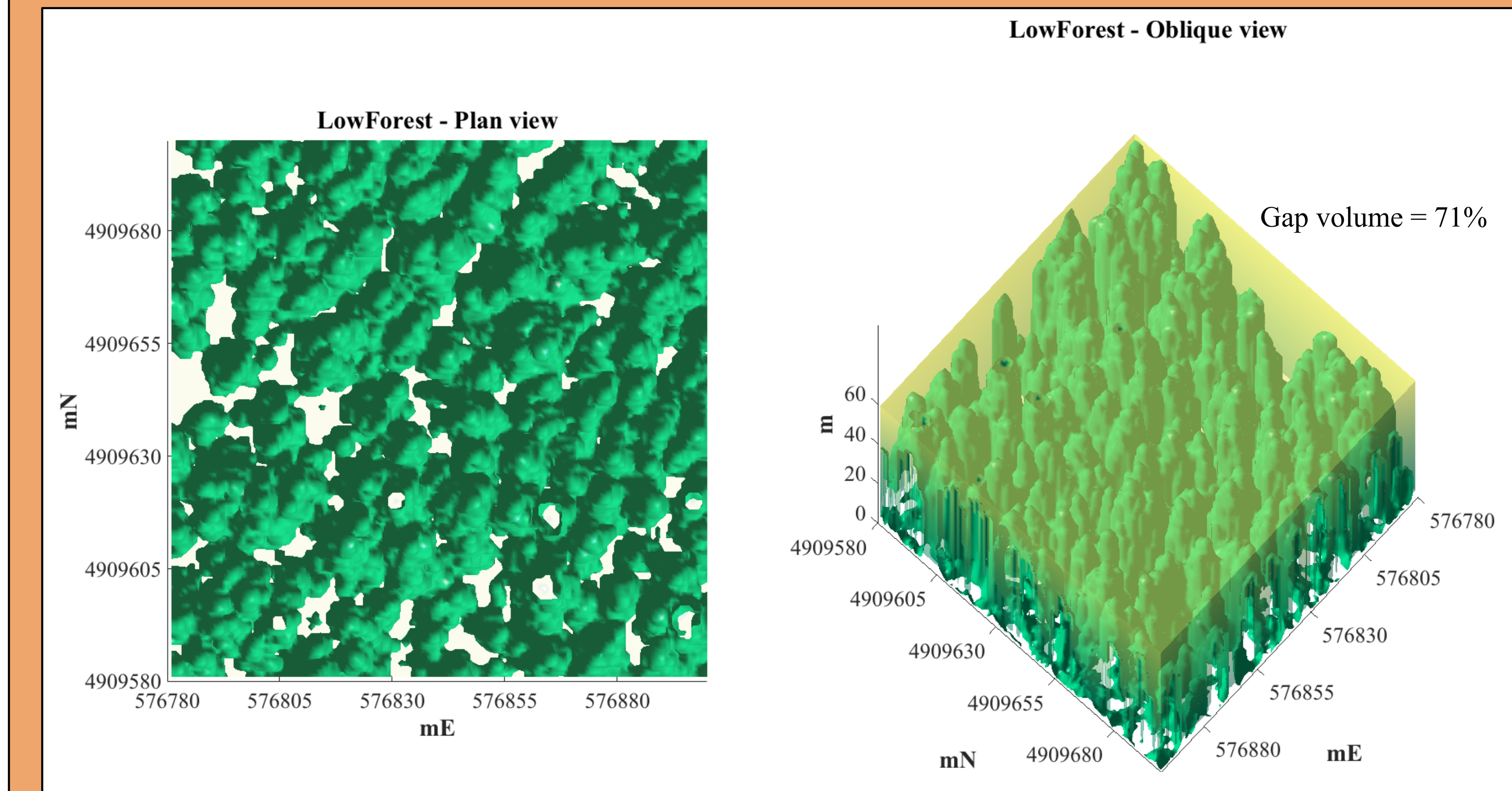


Figure 5: Plan view and oblique view of the Low-Forest site canopy volume (green) and gap volume (yellow).

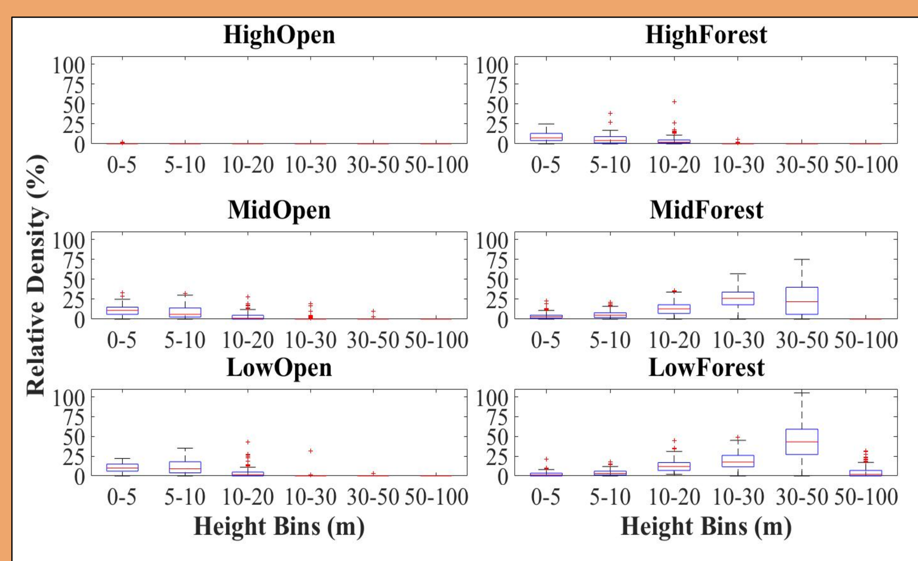


Figure 6: Binned relative height densities for each site.

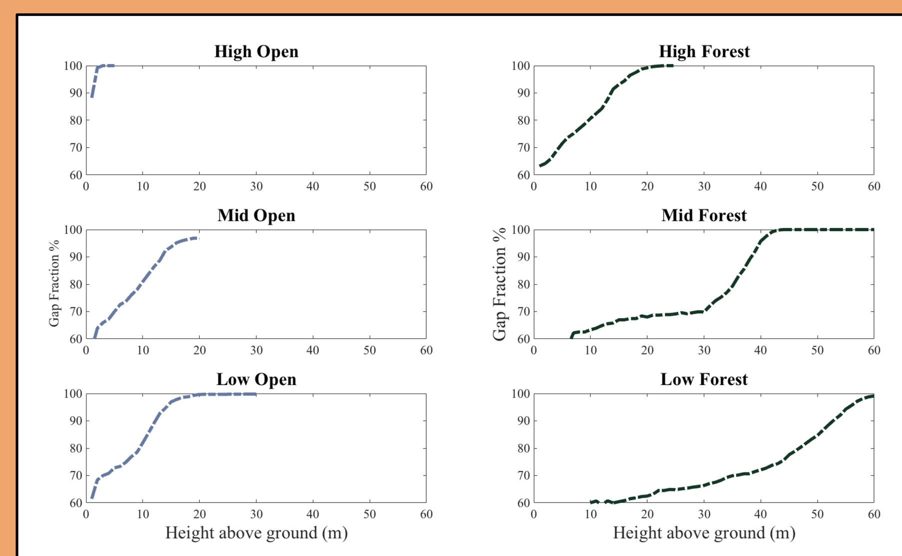


Figure 7: Calculated gap fraction vs. height.

## Results

- Vertical canopy metrics can be effectively calculated using lidar across various forest densities.
- Change of gap size with height can have significant effects of how a forest interacts with snow through variations of the wind field to canopy surface area available for interception. The change of gap size with height is a unique metric that can be determined through individual 'slice' analyzation techniques.

### Stereology and gap size

- Stereology is an effective method in determining mean gap length and volumetric gap size of a forest data cube. Figure 8 shows an example of an gap length profile output for a single vertical slice from the Low Forest. At each point a vertical and horizontal gap length is calculated to give a 3-d gap length.
- Figure 9 shows the mean gap length with height (red) and the surface volume of the canopy clusters (blue). The shape of the exponential curve of the blue line (SSV) gives an indication of the heterogeneity of the forest structure.

### Future Work

- A differential snow depth dataset from ASO lidar will statistically determine the relationships between forest metrics and snow depth across the ForEST network.
- Analysis of scale effects on forest metrics to determine effectiveness of new metrics as a means to better predict snow-forest process relationships and better simulate seasonal snow in forest environment.

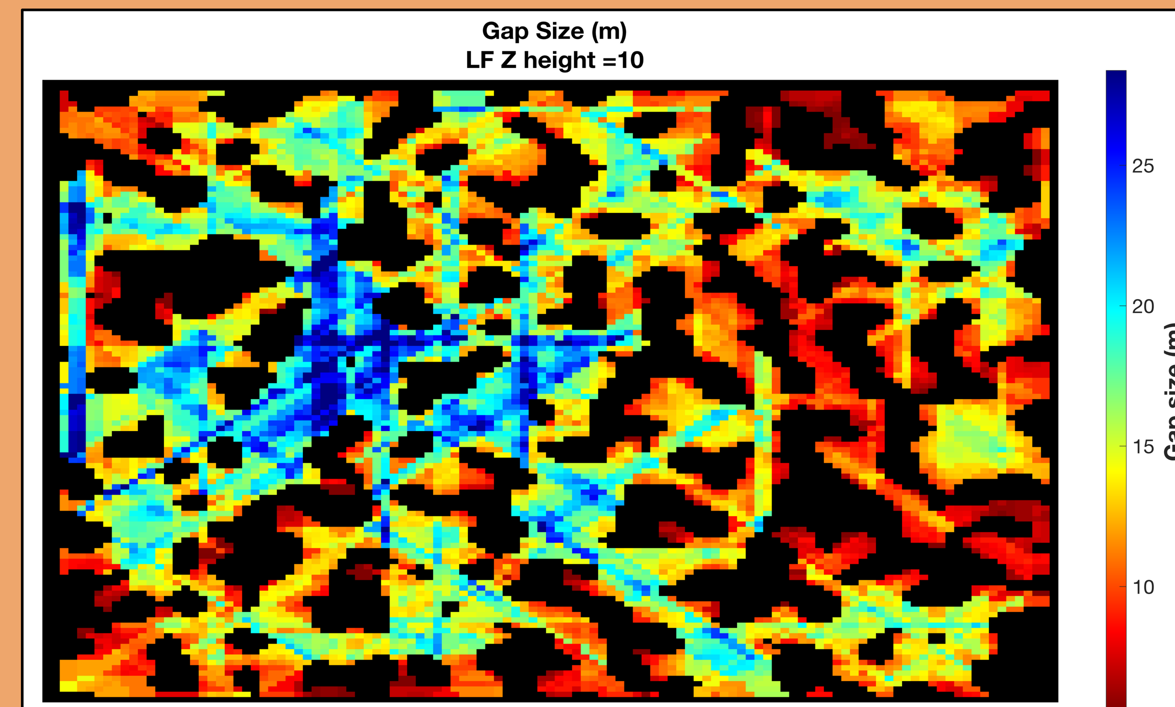


Figure 8: Low-Forest mean gap length at z = 10m

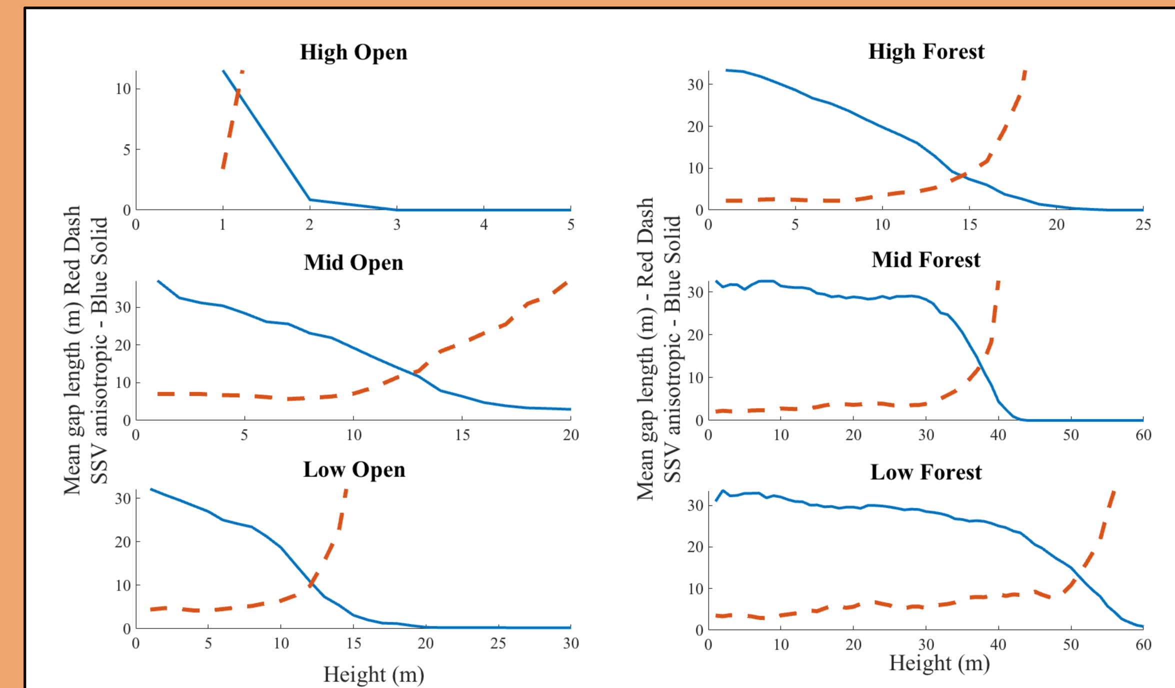


Figure 9: Mean gap length vs. Canopy cluster surface area per unit volume (SSV).

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**References:** Davis R. and Dozier J., Stereological characterization of dry alpine snow for microwave remote sensing. *Adv. Space Res.* Vol. 9, No. 1, 1989.

Lehto et al., Influence of grain size distribution on the Hall-Petch relationship of welded structural steel. *Materials Science and Engineering:* A, 2014 http://dx.doi.org/10.1016/j.msea.2013.10.094